

# **Annual Project Summary Report**

## **The New England Seismic Network**

USGS Award Number 04HQAG0020

PI [John E. Ebel](#)

Weston Observatory  
Boston College  
Department of Geology and Geophysics  
381 Concord Rd.  
Weston, MA 02493

Tel: 617-552-8300

Fax: 617-552-8388

Email: [ebel@bc.edu](mailto:ebel@bc.edu)

URL: <http://www.bc.edu/westonobservatory>

## **Project Summary**

The operation of a regional seismic network to monitor earthquake activity in New England and vicinity is supported under this project. The purpose of this earthquake monitoring is to compile a complete database of earthquake activity in New England to as low a magnitude as possible in order to understand the causes of the earthquakes in the region, to assess the potential for future damaging earthquakes, and to better constrain the patterns of strong ground motions from earthquakes in the region. The New England Seismic Network (NESN) is operated by Weston Observatory of Boston College. This is a progress report for the time period from October 1, 2003 through September 30, 2004.

## **Regional Seismic Network Status**

The New England Seismic Network (NESN) is operated by Weston Observatory of Boston College. During the time period of this report, the Weston Observatory component of the network was comprised of 12 seismic stations (Figure 1). Eleven of the seismic stations are located within New England, while there is one station at Troy, NY.

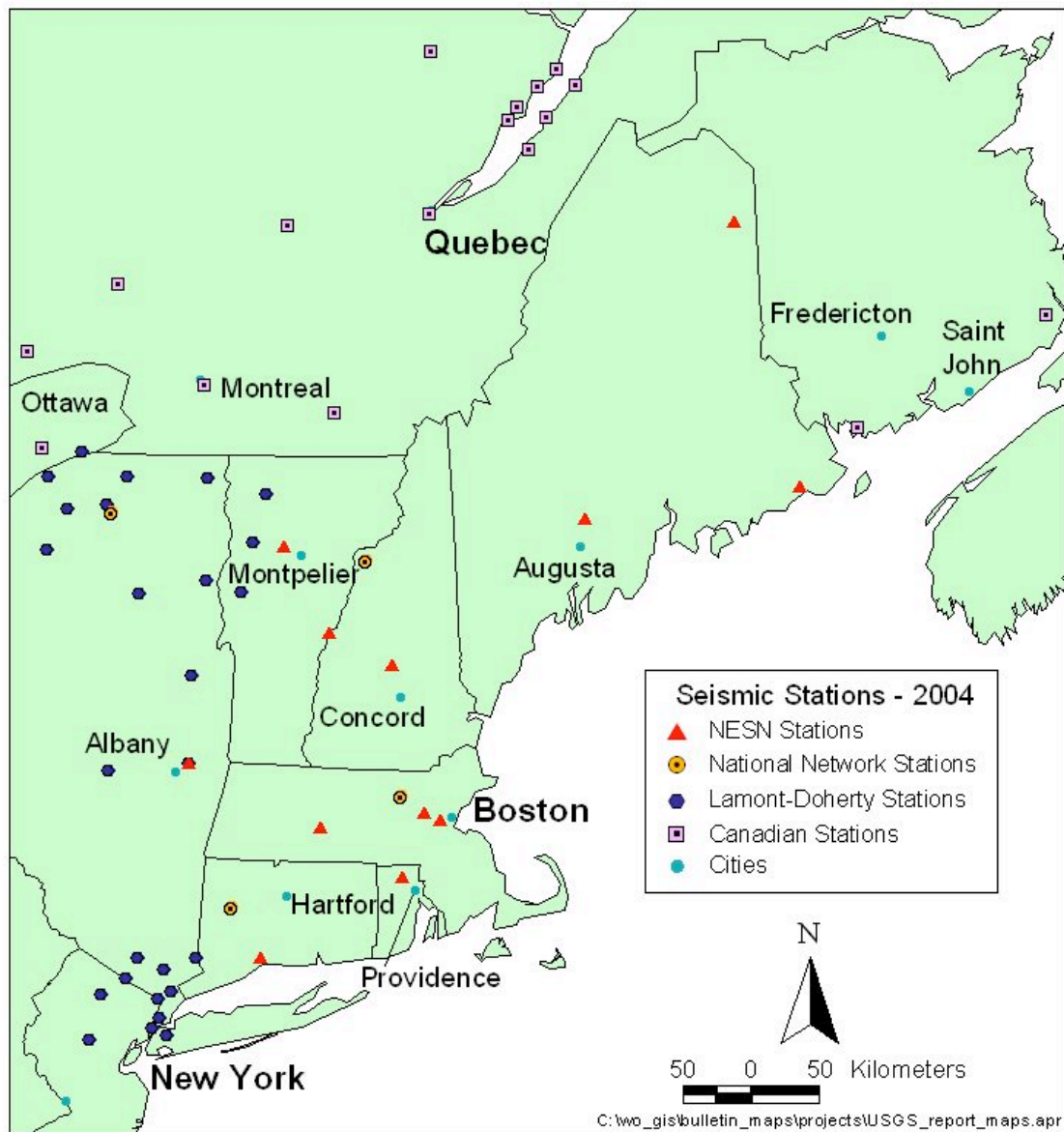


Figure 1. Stations of the Weston Observatory New England Seismic Network and other northeast networks from October 1, 2003 to September 30, 2004.

Throughout the period of this report, each of the NESN stations was comprised of one of two different types of seismic instrumentation. Five of the stations (BRY, FFD, HNH, QUA2 and WES) had new instrumentation from Refraction Technology, Inc. for digitizing and transmitting the seismic data at the remote stations. These systems, which were installed in September 2003, use 24-bit digitization and RTP to USGS for data transmission. The sensors, which had been installed previously, were CMG-40T feedback geophones with a flat response to ground velocity between roughly 30 Hz and 30 sec. The sites with the new digitization and recording equipment provide continuous seismic data, digitized at 40 samples/second, directly to the NEIC in Golden, CO, which in turn sends the continuous data to Weston Observatory via Earthworm.

Six of the NESN sites continued to use older PC-based data logging systems with on-site recording, three-component broadband sensors, and dial-up telephone telemetry or direct internet links to the central station at Weston Observatory. The sensors at these sites were also CMG-40T feedback geophones. The digitizers were Nanometrics 16-bit digitizers with gain-ranging, yielding effectively 136 db dynamic range. The sensor signals were being digitized at a rate of 100 samples per second per channel. At each station, the output from the digitizer was sent to a PC computer using OS/2, a multitasking operating system, at the digitizing site. The software controlling the stations stored the signals from the sensor in a continuous disk loop that was overwritten after about 3 weeks. Five of the sites (BCX, EMMW, PQI, WVL, and YLE) were available via internet connection to Weston Observatory, three of which (EMMW, PQI and WVL, all stations in Maine) were also sending their data to the USGS NEIC in Golden, Colorado. One station (TRY at Troy, NY) was not operational throughout this reporting period as it awaited new station equipment.

At each station with the older Nanometrics equipment the signals from the seismometer were recorded on a local hard disk. The datastream from the digitizer was examined by a program that used a filter and STA/LTA scheme to test for possible events. When the STA/LTA threshold was exceeded, a notation of the time and duration of the exceedence was added to a text file on the recording computer. An analyst at Weston Observatory used this detection file from a station to determine the possible times at which events may have been contained on the remote disks. The analyst then used these times to send requests to the remote stations to transmit windows of waveform data back to Weston Observatory for analysis. The retrieved waveforms from all stations were analyzed and archived at Weston Observatory.

In the summer of 2004 the USGS provided to Weston Observatory an additional five new systems from Refraction Technology, Inc. to upgrade another set of the NESN stations and to make station TRY operational once again. As of September 30, 2004, most of the new equipment had been received at Weston Observatory, but cables to connect to the seismometers and to the GPS receivers for station timing had not yet arrived. Thus, installation of these five new stations was delayed until the late fall or winter of 2004 after all the necessary station parts were in hand and tested.

During the time period covered by this report, Weston Observatory staff continued to develop new ways to make use of the seismic data being delivered by Earthworm for routine earthquake monitoring and event processing. Throughout this reporting period, Weston Observatory received continuous data via Earthworm from its five Reftek stations (BRY, FFD, HNH, QUA

and WES), triggered data from its stations EMMW, PQI, and WVL in New England, and continuous data from USNSN and USNSN-cooperative stations BINY, HRV, LBNH, and NCB. The data from these stations were being used in a routine manner in Earthworm's Waveviewer module to check the times of possible event detections.

Throughout the period of this report, Weston Observatory continued to modify and improve its wavelet-transform based automated event detector and identifier. An older version of this system was initially created and tested by Gendron et al. (2000) for the PC-based regional seismic network stations operated by Weston Observatory. An initial version of a new wavelet-based automated event detector and identifier, written in Matlab for use with the Earthworm datastreams, began routine operation at Weston Observatory in August, 2003. This software system carried out a wavelet transform on the data from each station being received via Earthworm, and then it looked for detections of possible seismic events within each data stream based on the amplitude of the wavelet-transform coefficients. Once a possible event was detected, the time, wavelet-transform scale (i.e., frequency band) and energy of the event beginning was measured, along with the same parameters for the highest amplitude of the detected event. A measurement of the end time of the event (when it dropped below the detection threshold) was also made. Using these seven event measurements, a calculation was carried out, similar to that described by Gendron et al. (2000), to compute the Bayesian probability that the detection was a teleseism, regional earthquake, local earthquake, quarry blast, Rg wave from a quarry blast, or transient noise. The event type with the highest probability was considered the most likely identification for the detected event. This event detection algorithm was refined during the fall of 2003 and the winter of 2004, and it has become quite successful at sorting the 5-15 earthquakes and quarry blasts from the hundreds of noise detections that are picked up each day by the seismic stations in the Earthworm data stream.

During the spring and summer of 2004 significant further improvements were made in the automated wavelet-transform event detection and identification system. The code was modified to use the wavelet-transform event parameter measurements to estimate the origin time, epicentral distance and magnitudes (both coda-wave magnitude  $M_c$  and Lg-wave magnitude  $M_{Lg}$ ) for each detection. An event associator was then written to associate detections from different stations that have coincident event origin times. If three or more stations were found to have associated origin times, an automatic event location and set of  $M_c$  and  $M_{Lg}$  magnitudes were computed under the assumption that a local or regional event had been detected. In late September 2004 the automated event locator was enhanced to send an email to selected internet addresses immediately after the event location and magnitude had been generated. This system remained under testing and refinement at the end of this reporting period.

The wavelet-transform event identifier and associator has proven to be quite robust at detecting seismic events, even for the spatially sparse regional seismic network that is being received via Earthworm at Weston Observatory. During the summer 2004, an average of about 12 quarry blasts and 1 teleseism were detected during weekdays, a rate that was higher than during previous summers. All local and regional earthquakes for which there was independent confirmation (i.e., either detected by another seismic network or reported felt by local residents) were also picked up by the detection system. Most importantly, the system led to the successful

detection of two small local earthquakes in New England for which there had been no felt reports. Thus, not only is the wavelet-transform event identifier and associator increasing the reliability of earthquake detections on the Earthworm data streams, it is also lowering the detection threshold for earthquakes in the New England region monitored by Weston Observatory.

To further improve the reliability of the event identification system, a second event identifier was under investigation as part of the wavelet-transform system (Zhu and Ebel, 2004; Ebel, 2004). This second system makes use of the amplitudes at all scales (an approximate frequency spectrum) of the beginning of an event detection to attempt to identify the type of seismic event that is being detected. Not only can this system aid in event identification, but it could also be adapted for use as an immediate event identifier as part of a seismic early warning system. The Zhu and Ebel (2004) event identification system still must undergo further refinement before it can be used reliably.

There remain some data processing shortcomings with the Earthworm data being received at Weston Observatory that must still be addressed. While the implementation of Earthworm has speeded up the routine analysis of event detections by the regional seismic network, it has slowed the computation of event magnitudes when earthquakes are analyzed. This is because the version of Earthworm's Waveviewer module currently being used at Weston Observatory does not provide a means to measure the amplitudes of the seismic signals it displays. Also, this version of Waveviewer does not have implemented any filtering of the seismic traces. Thus, it is not possible with the Waveviewer system to remove either low-frequency or high-frequency background noise from earthquake signals. These problems are being addressed at the present time by investigating other software packages that can be used for routine processing of the seismic data.

Weston Observatory continues to investigate finding new sites for regional seismic network stations in New England. Weston Observatory personnel have continued to work with the Maine Geological Survey and the USGS to site a USNSN national backbone station in central Maine. An acceptable site has been identified, and USGS personnel carried out preliminary investigations of the site toward the end of this reporting period. Weston Observatory is also working with universities in Keene, NH, Farmington, ME and Orono, ME to develop new seismic stations at or near those universities. Finally, Weston Observatory has been working with officials at a dam near Springfield, MA to bring the data from a digital strong-motion station on-line via the internet. It is ultimate the goal of Weston Observatory to bring the strong-motion data from this station into Weston Observatory via Earthworm and to incorporate the data into the routine event processing scheme. Once implemented, this would be the first real-time stream of strong-motion data directly to Weston Observatory from a site in New England.

Weston Observatory continues to cooperate with other regional network operators in northeastern North America (Lamont-Doherty Earth Observatory, the USGS NEIC, and the Canadian Geological Survey) in earthquake detection and analysis for events in the region. Event arrival time readings, waveforms, and hypocentral information are routinely exchanged between the Weston Observatory and these other groups. Weston Observatory continues to produce a quarterly seismic network bulletin for the New England area. That bulletin is produced

in html format and is posted on the Weston Observatory web pages as soon as possible after the quarter ends. List of recent earthquakes are also maintained on the Weston Observatory web site, along with links to other important sites with earthquake information for the region.

## **Accomplishments During the Report Period**

### **Seismic Monitoring**

The Weston Observatory NESN seismic stations detected a number of earthquakes from New England and vicinity from October 1, 2003 to September 30, 2004. A total of 15 local and regional earthquakes from New England and vicinity with magnitudes from 1.8 to 4.0 were detected and located by the network (Figure 2), some of which were locally felt. In addition to these events, some microearthquakes and suspected events, too small to be located, were detected by the network. The number of earthquakes during this reporting period is somewhat less than that from recent years.

For the first time since 1998, no earthquake of magnitude 3.0 or greater took place in New England over the 12-month period of this report. Felt earthquakes were reported from West Warwick, RI (magnitude 1.8), near Concord, NH (magnitude 2.5 and magnitude 2.4), and Dartmouth, MA (magnitude 2.0). The USGS “Did You Feel It?” web site gathered felt reports for all of these events. One event that was not felt but was detected by the wavelet-transform event detection system described in the previous section of this report was a magnitude 2.1 event that was centered offshore northeast of Cape Neddick, ME. This earthquake took place at the northern end of an offshore trend of events, detected since 1975, that runs roughly from south of Portland, ME to east of Cape Ann, MA. The southern end of this zone is thought to be where the 1755 M 6 earthquake was centered, and the entire zone may be indicating a possible seismically active structure in the offshore geology.

During this reporting period, Weston Observatory continued its web site offering weekly estimates of the probability of a felt earthquake in New England. The temporal probability is based on the work of Ebel and Kafka (2002), while the spatial probability is based on research published by Kafka and Levin (2000) and Kafka (2002). A link called “Earthquake Probability” on the Weston Observatory web page ([www.bc.edu/westonobservatory](http://www.bc.edu/westonobservatory)) shows the probability of a felt earthquake in New England for each upcoming 7-day period. Also shown on this web page is a map of those areas in New England that have about a 67% probability of being the epicenter of an earthquake of  $ML_g \geq 2.7$  during the 7-day period. With the low earthquake magnitude detected in New England during this reporting period, there were no earthquakes large enough to trigger a forecast of increased earthquake probability.

# New England Seismic Network Seismicity, 10/1/03 to 9/30/04

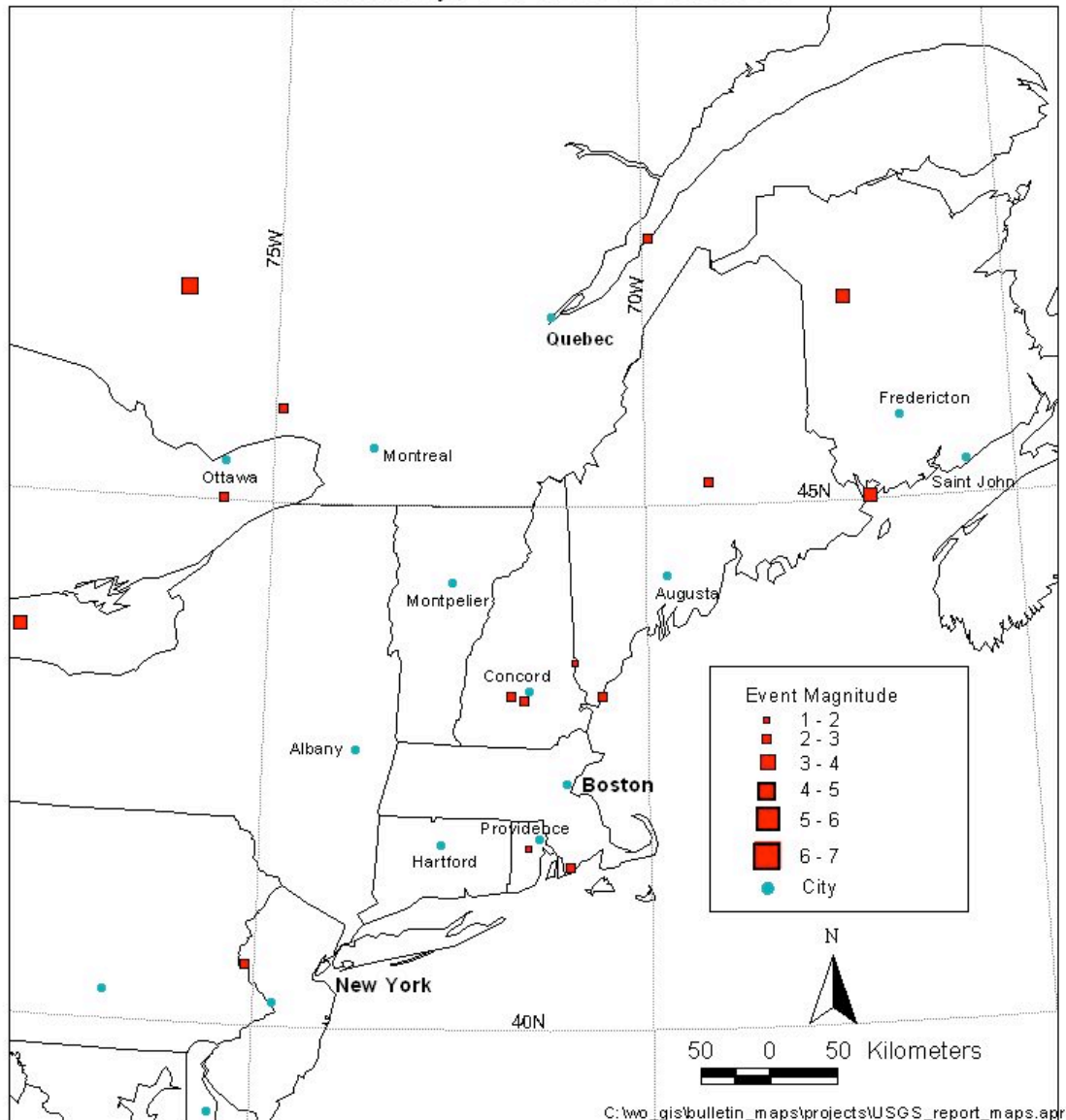


Figure 2. Seismicity of the northeastern U.S. and southeastern Canada detected by the Weston Observatory New England Seismic Network from October 1, 2003 to September 30, 2004.

## Data Dissemination

Weston Observatory continues to archive the waveform data for the seismic stations which they are operating. Weston Observatory has the capability to convert the waveforms, routinely stored in Nanometrics format PC stations, to either ASCII or SAC for external distribution. Weston Observatory is working to develop capabilities to deliver SEED waveforms of local events to the IRIS DMC, but that work was not completed by the end of this report period. Also, Weston Observatory contributes hypocentral data to the CNSS composite catalog on a routine basis as soon as possible after local earthquakes take place.

Weston Observatory maintains a web site with information about local earthquakes:

- <http://www.bc.edu/westonobservatory>

Currently available on the web page is the full catalog of northeastern earthquake activity to 2004 along with recent quarterly reports of the seismicity detected by the NESN. Weston Observatory attempts to regularly maintain and update its web pages with the latest information on earthquakes in the region.

## Financial Report and Personnel Status

During the time period of this report, the funding for this project was spent in accordance with the arrangements agreed upon in the cooperative agreement between Boston College and the USGS. There was one important change in personnel for this project during the reporting period. Edward (Ned) Johnson, who had been project engineer since 1982, retired during the summer of 2004. As search to replace him was commenced in late summer 2004, and shortly after the end of this reporting period an agreement was reached with Dr. Michael Hagerty to replace Ned Johnson. Mike Hagerty plans to start work in January 2005.

## References

- Ebel, J.E. (2004). Update on a Wavelet-Based Event Detector and Identifier at Weston Observatory, *Seism. Res. Lett.* **75**, in press.
- Ebel, J.E. and A.L. Kafka (2002). A Non-Poissonian Element in the Seismicity of the Northeastern United States, *Bull. Seism. Soc. Am.* **92**, 2040-2046.
- Gendron, P.A., J. Ebel and D. Manolakis (2000). Rapid Joint Detection and Classification with Wavelet Bases via Bayes Theorem, *Bull. Seism. Soc. Am.*, **90**, 764-774.
- Kafka, A.L. (2002). Statistical Analysis of the Hypothesis that Seismicity Delineates Areas Where Future Large Earthquakes Are Likely to Occur in the Central and Eastern United States,



*Seism. Res. Lett.* **73**, 992-1003.

Kafka, A.L. and S.Z. Levin (2000). Does the spatial distribution of smaller earthquakes delineate areas where larger earthquakes are likely to occur?, *Bull. Seism. Soc. Am.*, **90**, 724-738.

Zhu, L. and Ebel, J.E. (2004). Automated Seismic Signal Identification Algorithm for the New England Seismic Network Based on a Seismic Signal/Noise Ration (SNR) Spectral Model, *Seism. Res. Lett.* **75**, in press.